

FORM PTO-1590 (Modified)
(REV 11-2000)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

001/02614

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

10/070774

INTERNATIONAL APPLICATION NO.
PCT/IL99/00490

INTERNATIONAL FILING DATE
September 8, 1999

PRIORITY DATE CLAIMED

TITLE OF INVENTION
3D IMAGING SYSTEM

APPLICANT(S) FOR DO/EO/US
Gavriel J. IODAN, et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☒ has been communicated by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)). **UNEXECUTED**
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/PEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:
 1. Top sheet of the published international application
 2. Form PCT/IB/308
 3. Amendments to the International Application under PCT Article 34 are transmitted herewith as annexes to the IPER.

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 100070774	INTERNATIONAL APPLICATION NO. PCT/IL99/00490	ATTORNEY'S DOCKET NUMBER 001/02614
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24. The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

- | | |
|--|-----------|
| <input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO | \$1040.00 |
| <input checked="" type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO | \$890.00 |
| <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO | \$740.00 |
| <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) | \$710.00 |
| <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) | \$100.00 |

ENTER APPROPRIATE BASIC FEE AMOUNT =

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE
Total claims	34 - 20 =	14	x \$18.00
Independent claims	2 - 3 =	0	x \$84.00
Multiple Dependent Claims (check if applicable).			<input type="checkbox"/>

TOTAL OF ABOVE CALCULATIONS =

☐ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.

SUBTOTAL =

Processing fee of \$130.00 for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492 (I)). ☐ 20 ☐ 30

TOTAL NATIONAL FEE =

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable).

TOTAL FEES ENCLOSED

Amount to be: refunded	
charged	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466
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- a. ☐ A check in the amount of _____ to cover the above fees is enclosed.
- b. ☒ Please charge my Deposit Account No. 03-3419 in the amount of \$1,142.00 to cover the above fees.
A duplicate copy of this sheet is enclosed.
- c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 03-3419. A duplicate copy of this sheet is enclosed.
- d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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1133 Avenue of the Americas
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Tel: (212) 790-9200

Paul Fenster

SIGNATURE

Paul FENSTER

NAME _____

33,877

REGISTRATION NUMBER

March 6, 2002

DATE _____

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Gavriel J. IDDAN, et al.
Serial Number: Not Yet Assigned
Filed: September 8, 1999 as PCT/IL99/00490 and Herewith as U.S. National Stage
Title: 3D IMAGING SYSTEM
Art Unit: Not Yet Assigned
Examiner: Not Yet Assigned

Honorable Commissioner of Patents and Trademarks
Washington DC 20231

PRELIMINARY AMENDMENT

Sir:

Further to the concurrent filing of the U.S. national stage of PCT/IL99/00490, kindly amend the application as follows prior to examination:

IN THE SPECIFICATION

Kindly add the following section, on page 1, immediately after the title:

--RELATED APPLICATIONS

The present application is a U.S. national application of PCT/IL99/00490, filed September 8, 1999. —

IN THE CLAIMS

Please replace claims 3, 4, 7, 9, 11, 14 and 25-28 with the following amended claims in clean form:

CLAIMS

3. (Amended) An optical imaging system according to claim 1 wherein the at least one photosurface of the 3D camera and the at least one photosurface of the imaging camera are homologous.

4. (Amended) An optical imaging system according to claim 1 wherein the light control system comprises a light controller adjustable to control the amount of light from the taking lens system that reaches the imaging camera without affecting the amount of light from the taking lens system that reaches the 3D camera.

7. (Amended) An optical imaging system according to claim 1 wherein the light control system comprises a light controller adjustable to control the amount of light collected by the taking lens system that enters the imaging system.

9. (Amended) An optical imaging system according to claim 1 and comprising a light controller adjustable to control the amount of light from the taking lens system that reaches the 3D camera without affecting the amount of light from the taking lens that reaches the imaging camera.

11. (Amended) An optical imaging system according to claim 1 wherein the 3D camera is a gated 3D camera.

14. (Amended) An optical imaging system according to claim 11 wherein the 3D camera comprises at least 2 photosurfaces.

24. (Amended) An optical imaging system according to claim 15 wherein the light guide is a three-way prism.

25. (Amended) An optical imaging system according to claim 1 and comprising a beam splitter that receives light from the taking lens system and directs a portion of the received light towards the 3D camera and a portion of the received light to the imaging camera.

26. (Amended) An optical imaging system according to claim 7 wherein the light guide is a four-way prism that receives light from the taking lens system and directs a portion of the received light to the imaging camera.

27. (Amended) An optical imaging system according to claim 1 wherein the imaging camera comprises a color camera.

28. (Amended) An optical imaging system according to claim 1 wherein the imaging camera is a color camera comprising separate R, G and B photosurfaces and comprising a four way prism that receives light from the taking lens system and directs a portion of the received light to each of the R, G and B photosurfaces and to the single shutter of the 3D camera.

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REMARKS

This application is submitted as a National Phase Application of the above-referenced PCT application.

The present amendments are based on the claim set attached to the IPER and not the claims submitted with the originally filed PCT application. Applicants note that all the claims in the claim set attached to the IPER are indicated in the IPER as meeting the criteria of PCT Articles 33(2) - 33(4). The present amendments are made to place the claims in proper U.S. form.

A marked-up version of the amendments made to the IPER claim set is attached hereto.

In view of the favorable IPER, applicants submit that the application is in order for allowance. An action on the merits is respectfully awaited.

Respectfully submitted,
Gavriel J. IDDAN, et al.

Paul Fenster

Paul FENSTER
Reg. No. 33,877

March 6, 2002

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Tel: (212) 790-9200

MARKED-UP AMENDED CLAIMS

3. (Amended) An optical imaging system according to claim 1 ~~or claim 2~~ wherein the at least one photosurface of the 3D camera and the at least one photosurface of the imaging camera are homologous.

4. (Amended) An optical imaging system according to claim 1 ~~any of the preceding claims~~ wherein the light control system comprises a light controller adjustable to control the amount of light from the taking lens system that reaches the imaging camera without affecting the amount of light from the taking lens system that reaches the 3D camera.

7. (Amended) An optical imaging system according to claim 1 ~~any of the preceding claims~~ wherein the light control system comprises a light controller adjustable to control the amount of light collected by the taking lens system that enters the imaging system.

9. (Amended) An optical imaging system according to claim 1 ~~any of the preceding claims~~ and comprising a light controller adjustable to control the amount of light from the taking lens system that reaches the 3D camera without affecting the amount of light from the taking lens that reaches the imaging camera.

11. (Amended) An optical imaging system according to claim 1 ~~any of the preceding claims~~ wherein the 3D camera is a gated 3D camera.

14. (Amended) An optical imaging system according to claim ~~any of claims 11 -13~~ wherein the 3D camera comprises at least 2 photosurfaces.

24. (Amended) An optical imaging system according to claim ~~any of claims 15 -23~~ wherein the light guide is a three-way prism.

25. (Amended) An optical imaging system according to claim ~~any of claims 1 -24~~ and comprising a beam splitter that receives light from the taking lens system and directs a portion of the received light towards the 3D camera and a portion of the received light to the imaging camera.

26. (Amended) An optical imaging system according to claim ~~any of claims 7 -23~~ wherein the light

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guide is a four-way prism that receives light from the taking lens system and directs a portion of the received light to the imaging camera.

27. (Amended) An optical imaging system according to claim 1 ~~any of the preceding claims~~ wherein the imaging camera comprises a color camera.

28. (Amended) An optical imaging system according to claim ~~any of claims 1 - 24~~ wherein the imaging camera is a color camera comprising separate R, G and B photosurfaces and comprising a four way prism that receives light from the taking lens system and directs a portion of the received light to each of the R, G and B photosurfaces and to the single shutter of the 3D camera.

5/p2TS

3D IMAGING SYSTEM
FIELD OF THE INVENTION

The invention relates to cameras that provide an image of a scene and measurements of distances to regions in the scene.

5 **BACKGROUND OF THE INVENTION**

3D cameras that provide distance measurements to objects and points on objects that they image are well known in the art. Gated 3D cameras comprise a photosensitive surface, such as a CCD or CMOS camera, hereinafter referred to as a "photosurface", and a gating means for gating the camera open and closed, such as an electro-optical shutter or a gated image intensifier. To image a scene and determine distances from the camera to objects in the scene, the scene is generally illuminated with a train of light pulses radiated from an appropriate light source. Generally, the radiated light pulses are infrared (IR) light pulses. For each radiated light pulse in the train, following an accurately determined delay from the time that the light pulse is radiated, the camera is gated open for a period of time, hereinafter referred to as a "gate". Light from the light pulse that is reflected from an object in the scene is imaged on the photosurface of the camera if it reaches the camera during the gate. Since the time elapsed between radiating a light pulse and the gate that follows it is known, the time it took imaged light to travel from the light source to the reflecting object in the scene and back to the camera is known. The time elapsed is used to determine the distance to the object.

20 In some of these 3D cameras, only the timing between light pulses and gates is used to determine distance from the 3D camera to a region in the scene imaged on a pixel of the photosurface of the 3D camera. In others, the amount of light registered by the pixel during the time that the camera is gated open is also used to determine the distance. In 3D cameras in which the amount of light is used to determine distances to the imaged region, the amount of light registered on a pixel is sometimes corrected for reflectivity of the imaged region, dark current and background light. The accuracy of measurements made with these 3D cameras is a function of the rise and fall times and jitter of the light pulses and their flatness, and how fast the gating means can gate the camera open and closed.

30 Gated 3D cameras that determine distances to objects in a scene that they image responsive to amounts of light registered on pixels of photosurfaces comprised in the 3D cameras are described in PCT Publications WO 97/01111, WO 97/01112, and WO 97/01113, the disclosures of which are incorporated herein by reference.

WO 01/18563

PCT/IL99/00490

A gated 3D camera as shown in WO 97/01111 comprises first and second homologous photosurfaces and a light source that illuminates a scene being imaged with the camera with a train of, preferably IR, light pulses. The first photosurface, hereinafter referred to as a "distance photosurface", is gated on with a short gate following the time that each light pulse in the pulse train is radiated. The portion of light from each light pulse in the pulse train that is reflected by a region of the scene and enters the 3D camera, which is registered on a pixel of the distance photosurface, is a function of the distance of the region from the pixel. The second photosurface, hereinafter referred to as a "normalization photosurface", is preferably not gated. The portion of light from each light pulse in the pulse train that is reflected by a region of the scene and enters the 3D camera, which is registered on a pixel of the normalization photosurface, is independent of the distance of the region from the pixel. The amount of light registered on the pixel is a measure of the total amount of light reaching the camera from the imaged region. An amount of reflected light registered on a pixel of the distance photosurface from all the light pulses in the pulse train is normalized to an amount of reflected light from all the light pulses registered on a corresponding pixel in the normalization photosurface. Normalized amounts of light are used to determine distances to regions in the scene.

US patent 5,434,612 to Nettleton, the disclosure of which is incorporated herein by reference, describes a gated 3D camera comprising first, second and third photosurfaces. A scene imaged with this camera is not illuminated with a train of light pulses but with a single light pulse from a laser and the three photosurfaces are gated with respect to the time that the light pulse is radiated. The first photosurface is a distance photosurface. It is gated with a short gate so that a portion of the light pulse reflected by a region of the scene that is collected by the camera and registered on a pixel of the photosurface is a function of the distance of the region from the pixel. The second photosurface is a normalization photosurface. It is gated with a long gate so that the amount of reflected laser light registered on a pixel of the photosurface from an imaged region is a measure of the total amount of light reaching the camera from the imaged region. The third photosurface is used to measure background light by measuring the amount of light reaching the camera in a band of wavelengths near to wavelengths of light radiated by the laser. A filter that transmits light in the band of wavelengths close to the wavelength of the laser light but blocks light having a wavelength the same as a wavelength of light radiated by the laser shields the third photosurface. The third photosurface is gated simultaneously with the normalization photosurface by a long gate having a same gate width as the gate that gates the

second photosurface. A photosurface used to measure background light is hereinafter referred to as a "background photosurface".

Amounts of light registered on the background photosurface are used to correct the amounts of light registered on pixels of the distance and normalization photosurfaces for background light. Background corrected amounts of light registered by pixels on the normalization photosurface are used to normalize background corrected amounts of light registered by pixels on the distance photosurface. Distances to regions in the scene are determined from the background corrected normalized amounts of light registered by pixels on the distance photosurface.

Generally photosurfaces used in 3D cameras are gated by an external fast shutter. Certain types of CCD cameras allow for gating image acquisition on and off during a frame by turning the photosurfaces on and off. However, turn-on and turn-off times of these photosurfaces are generally much too long to enable gating the photosurfaces for the purposes of accurate distance measurements by turning them on and off. Typically turn-on and turn-off times for CCD photosurfaces are on the order of microseconds while gating for accurate distance measurements requires turn-on and turn-off times on the order of nano-seconds or less.

An electro-optical shutter suitable for use in 3D cameras, such as those described in the cited patent and patent applications is described in PCT Publication WO 99/40478, the disclosure of which is incorporated herein by reference.

Generally, a 3D camera is used in conjunction with an imaging camera, such as a video camera, that provides an image, hereinafter referred to as a "picture", of a scene being imaged with the 3D camera responsive to visible light from the scene. The 3D camera provides a "depth map" of the scene while the imaging camera provides a picture of the scene. Distances provided by the depth map are associated with visible features in the picture. In some applications distances associated with a picture of a scene are used to "window" the scene and remove unwanted features and/or objects in the scene, such as for example a background, from the picture. Such applications are described in PCT publication in WO 97/01111 cited above.

PCT patent application PCT/IL98/00476, entitled "Distance Measurement with a Camera", by some of the same inventors as the inventors of the present invention, the disclosure of which is incorporated herein by reference, describes a photosurface comprising pixels each of which has its own circuit that is controllable to gate the pixel on or off. A single photosurface of this type is useable to simultaneously provide the functions of a distance, background and normalization photosurface of a 3D camera as well as an imaging camera.

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However, as the number of functions that the photosurface performs increases, the resolution of the photosurface decreases.

It is advantageous to have a simple robust optical system comprising a 3D camera and an imaging camera that is easily adjustable to simultaneously optimize quantities of light available from a scene imaged by the system that reach the cameras.

SUMMARY OF THE INVENTION

An aspect of some preferred embodiments of the present invention relates to providing an improved optical system, hereinafter referred to as a "3D imager", comprising a 3D camera and an imaging camera, for acquiring depth maps and pictures of a scene.

10 An aspect of some preferred embodiments of the present invention relates to providing a 3D imager that is relatively easily adjusted so that its 3D and imaging cameras may simultaneously receive optimum amounts of light available from a scene being imaged with the 3D imager.

15 An aspect of some preferred embodiments of the present invention relates to providing a 3D imager comprising an improved gating system for gating photosurfaces comprised in its 3D camera.

A 3D imager, in accordance with some preferred embodiments of the present invention, comprises a single taking lens boresighted with a gated 3D camera and an imaging camera. Preferably, the imaging camera is a color camera. Preferably the 3D camera comprises three photosensitive surfaces, a distance photosurface, a normalization photosurface and a background photosurface. Preferably, the 3D imager is used with a pulsed IR light source that illuminates a scene being imaged with the 3D imager with a train of preferably IR, light pulses. Light from the light pulses reflected by objects in the scene is used by the 3D camera to provide a depth map of the scene. Visual light from the scene is used by the imaging camera to provide a picture of the scene

25 While there is usually more than ample amount of visible light available to form a quality picture of the scene, the quantity of light available for the purpose of providing a depth map of the scene is usually small. As a result, the 3D imager usually requires that the taking lens be set to a much higher f-number to produce a quality picture of the scene than an f-number required to provide accurate distance measurements to the scene.

30 To provide proper control of the amounts of light reaching the 3D camera and the imaging camera, the 3D imager comprises a system that controls the amount of light reaching

the imaging camera from the taking lens independently of the amount of light reaching the 3D camera.

Preferably, the 3D camera comprises at least two irises. A first iris of the at least two irises controls the amount of visible light collected by the taking lens that reaches the imaging camera. A second iris controls either the amount of IR light collected by the taking lens that reaches the 3D camera or the total amount of IR and visible light collected by the taking lens that enters the 3D imager. As a result, the 3D imager can be adjusted to control independently amounts of light reaching the imaging camera and the 3D camera from a scene being imaged with the 3D imager. Therefore, subject to a level of illumination of the scene, a 3D imager, in accordance with a preferred embodiment of the present invention, is adjustable to simultaneously optimize the amounts of light from the scene that reach its 3D and imaging cameras.

In accordance with some preferred embodiments of the present invention all photosurfaces comprised in the 3D camera are gated with a same single fast shutter. This substantially simplifies the construction and control of the 3D imager. Preferably the 3D camera comprises three photosurfaces, a distance photosurface, a background photosurface and a normalization photosurface. The three photosurfaces are independently controllable to be turned on and off. Preferably, all light transmitted from the taking lens to the 3D camera passes through the single fast shutter. After passing through the shutter, portions of the light are directed to each of the three photosurfaces, for example by a prism. Preferably, the prism is a totally internal reflection (TIR) prism. At any given time, to determine which of the photosurfaces is gated by the fast shutter, all photosurfaces except a photosurface that is to be gated by the fast shutter are shut off.

It is to be noted that whereas the photosurfaces are controllable to be turned on or off, the speed with which a photosurface can be switched between on and off states is generally not fast enough to gate the photosurfaces for the purposes of accurate distance measurements. Therefore, for 3D cameras, gating photosurfaces by turning them on and off is generally not practical.

In some preferred embodiments of the present invention, the 3D camera and associated optical components are housed as a single unit, hereinafter referred to as a "3D module". The 3D module comprises portals for optically coupling a taking lens and imaging camera to the 3D module using methods and techniques known in the art. In some preferred embodiments of the

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present invention, the 3D camera, imaging camera and associated electrical and optical components are integrated together as a single unit to which a taking lens is optically coupled.

There is therefore provided, in accordance with a preferred embodiment of the present invention an optical imaging system comprising: a taking lens system that collects light from a scene being imaged with the optical imaging system; a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light.

Preferably, the 3D camera and the imaging camera are boresighted with the taking lens system. Additionally or alternatively, the at least one photosurface of the 3D camera and the at least one photosurface of the imaging camera are preferably homologous.

In some preferred embodiments of the present invention, an optical imaging system comprises a light controller adjustable to control the amount of light from the taking lens system that reaches the imaging camera without affecting the amount of light from the taking lens system that reaches the 3D camera. Preferably, the light controller comprises an iris. Alternatively, the light controller preferably comprises a neutral density filter.

In some preferred embodiments of the present invention, an optical imaging system comprises a light controller adjustable to control the amount of light collected by the taking lens system that enters the imaging system. Preferably, the light controller comprises an iris.

In some preferred embodiments of the present invention, an optical imaging system comprises a light controller adjustable to control the amount of light from the taking lens system that reaches the 3D camera without affecting the amount of light from the taking lens system that reaches the imaging camera. Preferably, the light controller comprises an iris.

The 3D camera in an optical imaging system in accordance with some preferred embodiment of the present invention is a gated 3D camera. Preferably, the optical imaging system comprises a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the optical imaging system. Preferably, the pulsed light source radiates IR light.

According to some preferred embodiments of the present invention, the 3D camera comprises at least 2 photosurfaces. Preferably, the 3D camera comprises a light guide that receives light from the taking lens system and directs portions of the light that it receives to

each of the at least two photosurfaces. Preferably, the 3D camera comprises a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

The optical imaging system preferably comprises a controller that gates the single shutter open and closed. Preferably, the controller controls each of the photosurfaces to be
5 activated and deactivated and wherein when a photosurface is activated, it is sensitive to light incident thereon. Preferably, the controller gates on the single shutter it activates one and only one of the at least two photosurfaces.

Preferably, the at least two photosurfaces comprises three photosurfaces. Preferably, following a time that at least one light pulse is radiated, the controller gates on the single
10 shutter for a first gate and turns on a first photosurface and the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

Following a time that at least one light pulse in the train of light pulses is radiated, the controller preferably gates on the single shutter for a second gate and activates a second one of
15 the photosurfaces and the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

Preferably, following a time that at least one light pulse in the train of light pulses is radiated the controller gates on the single shutter for a third gate and activates a third one of the
20 photosurfaces and the controller controls the gate width and timing of the third gate so that during the third gate substantially all light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

In some preferred embodiments of the present invention the light guide of the 3D camera is a three-way prism.

Some optical imaging systems in accordance with preferred embodiments of the present
25 invention comprise a beam splitter that receives light from the taking lens system and directs a portion of the received light towards the 3D camera and a portion of the received light to the imaging camera.

In some preferred embodiments of the present invention the light guide of the 3D camera is a four-way prism that receives light from the taking lens system and directs a portion
30 of the received light to the imaging camera.

In some preferred embodiments of the present invention the imaging camera comprises a color camera.

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In some optical imaging systems, in accordance with preferred embodiments of the present invention, the imaging camera is a color camera comprising separate R, G and B photosurfaces and the imaging system comprises a four way prism that receives light from the taking lens system and directs a portion of the received light to each of the R, G and B photosurfaces and to the single shutter of the 3D camera.

There is further provided in accordance with a preferred embodiment of the present invention a gated 3D camera comprising: a taking lens system that collects light from a scene imaged with the 3D camera; at least 2 photosurfaces; a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces; and a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

Preferably, the controller controls each of the photosurfaces to be activated and deactivated and wherein when a photosurface is activated, it is sensitive to light incident thereon. Preferably, each time that the controller gates on the single shutter it activates one and only one of the at least two photosurfaces. Preferably, the at least two photosurfaces comprises three photosurfaces.

The 3D camera preferably comprises a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the 3D camera. Preferably, following a time that at least one light pulse is radiated, the controller gates on the single shutter for a first gate and turns on a first photosurface and the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

Preferably, following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter for a second gate and activates a second one of the photosurfaces and the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

Preferably, following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter for a third gate and activates a third one of the photosurfaces and the controller controls the gate width and timing of the third gate so that during the third gate substantially all light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

BRIEF DESCRIPTION OF FIGURES

The invention will be more clearly understood by reference to the following description of preferred embodiments thereof read in conjunction with the figures attached hereto. In the

figures, identical structures, elements or parts which appear in more than one figure are labeled with the same numeral in all the figures in which they appear. Dimensions of components and features shown in the figures are chosen for convenience and clarity of presentation and are not necessarily shown to scale. The figures are listed below.

5 Fig. 1 schematically shows a 3D imager comprising a 3D module, in accordance with a preferred embodiment of the present invention;

Fig. 2A schematically shows a 3D imager comprising a 3D module, in accordance with a preferred embodiment of the present invention;

10 Fig. 2B shows a timing diagram for shuttering photosurfaces comprised in the 3D imager shown in Fig. 2A, in accordance with a preferred embodiment of the present invention;

Fig. 3 schematically shows a 3D imager comprising a 3D module, in accordance with a preferred embodiment of the present invention; and

Fig. 4 schematically shows a 3D imager comprising a 3D module and color imager integrated in a single unit, in accordance with a preferred embodiment of the present invention.

15 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 schematically shows a 3D imager 20 comprising a 3D module 22, in accordance with a preferred embodiment of the present invention, shown inside dashed boundary 24. 3D module 22 comprises a beam splitter 26, two refocusing lens systems 28 and 30, referred to as "refocusers" 28 and 30, and a 3D camera 32 having components shown inside a dashed boundary 34. 3D module 22 is coupled to a taking lens system 35 and an imaging camera 36, which is shown by way of example as a video camera. Preferably, video camera 36 is a color video camera. Taking lens 35 and video camera 36 may be any suitable taking lens and video camera, for example a CCD or CMOS camera, readily available on the commercial market. A pulsed light source 38 radiates pulse trains of, preferably IR light pulses, to illuminate scenes 25 being imaged with 3D imager 20. 3D imager 20 is shown, by way of example, imaging a scene 40 having two elephants 42 and 44.

Visual light and IR light from IR source 38 that is reflected from scene 40 and collected by taking lens 35 is represented by large arrows 46. Collected light 46 is transmitted by taking lens 35 to beam splitter 26. Visual light, represented by arrows 48, in collected light 46, is 30 transmitted by beam splitter 26 and enters refocuser 28. Refocuser 28 generally comprises a field lens 50, an iris 52 and a relay lens 54. Refocuser 28 is boresighted with taking lens 35 and preferably positioned so that an image of scene 40 formed by taking lens 35 from visual light 48 is located substantially at the location of field lens 50. Light from field lens 50 passes

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through iris 52 and continues towards relay lens 54, which transmits the light to video camera 36. Video camera 36 is boresighted with refocuser 28 and taking lens 35. The amount of light received by video 36 from refocuser 28 is controlled by iris 52. Received visual light 48 is imaged by video 36 to form a picture of scene 40.

5 IR light, represented by dashed arrows 60, in collected light 46 that is incident on beam splitter 26 is reflected by beam splitter 26 to refocuser 30, which is boresighted with taking lens 35. Refocuser 30 is generally similar to refocuser 28 and preferably comprises a field lens 62, an iris 64 and a relay lens 66. Refocuser 30 is preferably positioned so that an image of scene 40 formed in IR light 60 by taking lens 35 is located at the location of field lens 62. Refocuser
10 30 transmits IR light that it receives towards 3D camera 32 which is boresighted with refocuser 30 and taking lens 35. The amount of IR light 60 transmitted by refocuser 30 to 3D camera 32 is controlled by iris 64.

Irises 52 and 64 are controllable independently of each other and therefore enable the amounts of IR and visual light reaching 3D camera 32 and video camera 36 respectively to be
15 controlled independently of each other, in accordance with a preferred embodiment of the present invention. 3D imager 20 therefore can easily be adjusted to simultaneously optimize the amounts of IR light reaching 3D camera 32 and visual light reaching video camera 36 from taking lens 35 to provide simultaneous quality depth maps and pictures of scene 40.

It is to be noted that commercially available taking lenses are generally supplied with
20 an iris and taking lens 35 is shown with an iris 67. In operation of 3D imager 20, iris 67 is preferably permanently set to maximum open and the amounts of light reaching 3D camera 32 and video camera 36 are controlled by irises 64 and 32 respectively. However, in some preferred embodiments of the present invention iris 67 is used in place of one of irises 52 or 64. For example, generally a greater fraction of IR light collected by taking lens 35 is needed to
25 produce a quality depth map of a scene than the fraction that is needed of visible light collected by taking lens 35 to provide a quality picture of the scene. As a result, iris 67 may conveniently be used in place of iris 64 to modulate IR light reaching 3D camera 32.

3D camera 32 preferably comprises a three-way prism 68 and preferably three
30 photosurfaces 71, 72 and 73. Three-way prism 68 receives IR light 60 transmitted from refocuser 30 and directs portions of the received IR light to each of photosurfaces 71, 72 and 73. Photosurfaces 71, 72 and 73 are respectively shuttered by fast shutters 81, 82 and 83. Fast shutters 81, 82 and 83, and fast shutters in other preferred embodiments of the present invention, are preferably either gated image intensifiers or fast solid state shutters of a type

described in above cited PCT patent application PCT/IL98/00060. In some preferred embodiments of the present invention in which 3D photosurfaces are shuttered individually by their own fast shutters, as are photosurfaces 71, 72 and 73, the shutters are comprised in the photosurfaces. Photosurfaces that comprise shuttering apparatus are described in PCT patent application PCT/IL98/00476 cited above. A controller (not shown) controls shutters 81, 82 and 83.

Photosurfaces 71, 72 and 73 function respectively as a distance photosurface, a background photosurface and a normalization photosurface and are labeled accordingly "D", "N" and "B" in Fig 1. The choice of which photosurface 71, 72 or 73 is a distance, background or normalization photosurface is arbitrary and the choices shown in Fig. 1 are choices of convenience. The controller controls shutters 81, 82 and 83 to gate photosurfaces 71, 72 and 73 following each IR pulse radiated by IR source 38 with a sequence of gates similar to prior art gate sequences used in gated 3D cameras. Prior art gating sequences are described in above cited references PCT Publications WO 97/01111, WO 97/01112, WO 97/01113, US Patent 5,434,612 and PCT Application PCT/IL98/00476.

Whereas, in the preceding paragraph it is implied that photosurfaces 71, 72 and 73 are similar or substantially identical, and this is generally the case, in some preferred embodiments of the present invention, different ones of the photosurfaces in 3D camera 32 are different. For example, a photosurface used to measure background light or normalization light may have a lower resolution than a resolution of a photosurface used as a distance photosurface and this can be advantageous.

Shutter 81 is controlled to respectively gate distance photosurface 71 with a relatively short gate and normalization photosurface 73 with a relatively long gate. Preferably the short gate has a gate width that is equal to the pulse width of IR pulses radiated by pulsed IR source 38. Preferably the time centers of the short gates and long gates coincide. The controller preferably controls shutter 83 to gate background photosurface 72 with a short gate. The short gate of background photosurface 72 is timed to occur when no IR light from pulsed IR source 38 that is reflected from scene 40 is incident on taking lens 35. Preferably the short gates of distance photosurface 71 and background photosurface 72 are equal. During the short gate of background photosurface 72, substantially only background light and dark current effects are registered by background photosurface 72.

The amounts of light registered on pixels of distance photosurface 71, background photosurface 72 and normalization photosurface 73 are sensed and transmitted to a processor

(not shown) using methods known in the art and processed as in prior art to provide a depth map of scene 40.

Photosurfaces comprised in 3D cameras and imaging cameras that are used in 3D imagers, in accordance with preferred embodiments of the present invention, are preferably homologous. Two photosurfaces are said to be homologous if there is a one to one mapping of regions of one of the photosurfaces onto the other and the positions of any two regions that map onto each other are similar in their respective photosurfaces

Fig. 2 shows another 3D imager 100 imaging scene 40. 3D imager 100 comprises a 3D module 102 optically coupled to taking lens 35 and video camera 36.

3D module 102, having components shown inside dashed boundary 104, is similar to 3D module 22. 3D module 102 comprises beam splitter 26 and refocuser 28 that transmits visual light 48 from taking lens 35 to video camera 36, which generates a picture of scene 40 responsive to the visual light that it receives. 3D module 102 comprises a 3D camera 106 having components shown inside dashed boundary 108.

However, unlike 3D module 22, 3D module 102 does not comprise a refocuser 30 that irises and transmits IR light from beam splitter 26 to 3D camera 106. Instead, IR light 60 from beam splitter 26 passes through a fast shutter 110 and a relay lens 112 that directs the IR light to 3D camera 106. Preferably, an iris 111 controls the amount of light from taking lens 35 transmitted to 3D camera 106. 3D camera 106 is similar to 3D camera 32 shown in Fig. 1 and comprises a three-way prism 68 that directs portions of IR light 60 incident on three-way prism 68 to a distance photosurface 121, a background photosurface 122 and a normalization photosurface 123. However, unlike photosurfaces 71, 72 and 73 in 3D camera 32, Photosurfaces 121, 122 and 123 are not individually gated by their own fast shutters as are photosurfaces 71, 72 and 73 in 3D camera 32. Fast gating for all photosurfaces 121, 122 and 123 is done by fast shutter 110, which is common to all photosurfaces 121, 122 and 123. Photosurfaces 121, 122 and 123 are turned on and off to determine which photosurface registers light during a gate of fast shutter 110. Preferably, only one photosurface is turned on during a gate of fast shutter 110.

Fast shutter 110 is controlled by a controller (not shown) to be gated open with a sequence of short and long gates in synchrony with IR pulses radiated by IR source 38. Preferably, two sequential short gates having a same gate width follow every other IR light pulse in a train of light pulses radiated by IR light source 38 to illuminate scene 40. Preferably, a long gate follows every IR pulse that is not followed by the two sequential short gates.

During the first short gate, IR light reflected from scene 40 is collected by taking lens 35 and transmitted to 3D camera 106 and only distance photosurface 121 is turned on. Only distance photosurface 121 registers amounts of light incident on 3D camera 106 during the first short gate. The amount of reflected IR light registered on distance photosurface 121 from a region of scene 40, compared to the total amount of reflected IR light reaching taking lens 35 from the region is useable to determine the distance of the region from 3D camera 106.

The timing of the first short gate with respect to an IR light pulse from which reflected light is registered by distance photosurface 121 and the gate width of the short gate, determine a center for a range of distances for which 3D camera 106 can provide distance measurements to regions in scene 40. The width of the range is determined by the pulse width of the IR pulses and the gate width of the short gate.

The second short gate is timed to occur when no IR light reflected from scene 40 reaches taking lens 35. During the second short gate only background light is collected by taking lens 35 and transmitted to 3D camera 106. Only background photosurface 122 is turned on and registers light incident on 3D camera 106. Background photosurface 106 exclusively acquires background light information from scene 40.

The time centers of the long gates and the first short gates are preferably delayed by the same time with respect to their respective IR light pulses. During the long gates, only normalization photosurface 123 is turned on. Normalization photosurface 123 registers amounts of IR light that are responsive to total amounts of reflected IR light reaching taking lens 35 from regions of scene 40.

It should be noted that, while photosurfaces 121, 122 and 123 are turned on and off to gate 3D camera 106, gating of 3D camera 106 for accurate distance measurements cannot be accomplished without fast gate 110 and only by turning on and off photosurfaces 121, 122 and 123. Accurate distance measurement require that photosurfaces 121, 122 and 123 be gated on and off in times on the order of nanoseconds or less. Photosurfaces such as CCD photosurfaces can generally be turned on and off in times on the order of microseconds.

However, whereas turning photosurfaces on and off can not generally be used for fast shuttering of photosurfaces, it can be used for irisng photosurfaces. For example, a photosurface in some video cameras can be turned off for a fraction of a frame time to control an amount of light that the photosurface registers. In some preferred embodiments of the present invention irisng of an imaging camera is accomplished by controlling the length of time that a photosurface comprised in the imaging camera is on during a frame time.

As in prior art, amounts of light registered on pixels of distance photosurface 121 are corrected for background and normalized using amounts of light registered on corresponding pixels of on background photosurface 122 and normalization photosurface 123. The corrected and normalized amounts of light are used to determine distances to reflecting regions of scene 40, in this case, by way of example distances to elephants 42 and 44.

Fig. 2B shows, as function of time, a graph 130 of gates of fast shutter 110 and associated periods of time, hereinafter referred to as "on times" during which photosurfaces 121, 122 and 123 are turned on, in accordance with a preferred embodiment of the present invention. The gates and on times are shown by way of example synchronized with four IR pulses, represented by rectangles 131, 132, 133 and 134 on a time line 136, of a pulse train of IR pulses radiated by IR source 38 shown in Fig. 2A to illuminate scene 40. The choice of four IR pulses in the train of pulses is by way of example only and is a choice of convenience.

The gates of fast gate 110 are represented by dashed rectangles 141, 142 and 143. Gates 141 are short "distance gates" and gates 142 are short "background gates". A distance gate 141 and a background gate 142 follow every other IR pulse (the odd numbered IR pulses in Fig. 2B) in the pulse train radiated by IR source 38. Gates 143 are long "normalization" gates that preferably follow every IR pulse (the even numbered IR pulses in Fig. 2B) that is not followed by a distance gate 141 and a background gate 142.

The on times of distance, background and normalization photosurfaces 121, 122 and 123 are shown as trapezoids 150 on timelines 151, 152 and 153 respectively. Distance photosurface 121 is on only during short distance gates 141. Background photosurface 122 is on only during short background gates 142 and normalization photosurface 123 is on only during long normalization gates 143. The sloped side edges of the trapezoids indicate the relatively long periods of time required to turn on and off a photosurface compared to the short turn-on and turn-off times required to gate photosurfaces quickly enough to provide accurate distance measurements.

An intensity of light received by taking lens 35 from elephant 42 as a function of time is represented by the height of an "intensity" line 160 above a base line 162. Rectangular "peaks" 164 in the height of intensity line 160 occur when IR light reflected from an IR pulse by elephant 42 reaches taking lens 35. The height of intensity line 160 outside of peaks 164 represents background light received from elephant 42. Amounts of light received from elephant 42 that are registered by photosurfaces 121, 122 and 123 during gates 141, 142 and 143 are represented by shaded areas 171, 172 and 173 respectively.

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Similarly, an intensity of light received by taking lens 35 from second elephant 44 as a function of time is represented by the height of an intensity line 180, which has IR "reflection peaks" 184, above a base line 182. Shaded areas 181, 182, and 183 represent amounts of light from second elephant 44 registered by photosurfaces 121, 122 and 123 during gates 141, 142 and 143 respectively.

For elephant 42, background corrected light registered by distance photosurface 121 is represented by an area equal to the sum of the areas 171 minus the sum of areas 172. Background corrected light registered by normalization photosurface 123 is represented by an area equal to the sum of areas 173 minus the product of the ratio of the gate width of long gates 143 to the gate width of short gates 142 times the sum of areas 173. For elephant 44, background corrected light registered by distance photosurface 121 is represented by an area equal to the sum of areas 181 minus the sum of areas 182. Background corrected light registered by normalization photosurface 123 for elephant 44 is represented by an area equal to the sum of areas 183 minus the product of the ratio of the gate width of long gates 143 to the gate width of short gates 142 times the sum of areas 183

Elephant 44 is further away from 3D imager 100 than elephant 42. As a result, the amount of background corrected light registered by distance photosurface 121 normalized to background collected light registered by normalization photosurface 123 is less for elephant 44 than for elephant 42.

Fig. 3 shows another 3D imager 200 imaging scene 40, in accordance with a preferred embodiment of the present invention.

Imager 200 comprises a 3D module 202 having components shown inside dashed border 204, which is coupled to taking lens 35 and video camera 36. 3D module 202 comprises a 3D camera 206 having components shown inside dashed border 208. 3D camera 206 comprises a four-way prism 210 that directs portions of IR light 60 in light 46 that is collected by taking lens 35 from scene 40 to distance, background and normalization photosurfaces 71, 72 and 73 respectively. Each of photosurfaces 71, 72 and 73 is gated by its own fast shutter 81, 82 and 83 respectively. Photosurfaces 71, 72 and 73 are gated similarly to the manner in which photosurfaces 71, 72 and 73 comprised in 3D camera 206, shown in Fig. 1, are gated. Amounts of IR light 60 collected by taking lens 35 that reaches 3D camera 206 is controlled by iris 67 comprised in taking lens 35.

Four-way prism 210 also directs visual light 48 in light 46 collected by taking lens 35 to a refocuser 28 that preferably comprises a field lens 50 an iris 52 and a relay lens 54. Refocuser 28 transmits visual light 48 that it receives from four-way prism 210 to video camera 36.

Fig. 4 schematically shows another 3D imager 220 imaging scene 40 in accordance with a preferred embodiment of the present invention. 3D imager 220 comprises a unit 222, hereinafter referred to as a "combination unit", having components located within a border 224. Combination unit 222 comprises a 3D camera 226 having components shown inside a dashed boundary 228 and three color cameras, a Red (R) camera 230 a Green (G) camera 232 and a Blue (B) camera 234. Combination unit 222 is coupled to a taking lens 35, which is boresighted with 3D camera 226 and color cameras 230, 232 and 234.

Combination unit 222 comprises a four-way prism 236 that directs visual light 48 collected by taking lens 35 to each of color cameras 230, 232 and 234 and IR light 60 collected by taking lens 35 to a fast shutter 110 that shutters 3D camera 226. Preferably, combination unit 222 comprises an iris 111 that controls the amount of light 60 transmitted from taking lens 35 to 3D camera 226. IR light 60 that fast shutter 110 transmits is incident on a relay lens 238 that relays the light to a three-way prism 68, which directs portions of the IR light 60 that it receives to a distance photosurface 121, a background photosurface 122 and a normalization photosurface 123. 3D camera 226 is substantially the same as 3D camera 106 shown in Fig. 2A and is gated by controlling fast shutter 110 and photo surfaces 121, 122, and 123 in the same manner in which 3D camera 106 is gated.

Whereas combination unit 222 is shown comprising a 3D camera in which all the photosurfaces are shuttered by single shutter, in some preferred embodiments of the present invention, combination unit 222 comprises a 3D camera similar to 3D camera 32 shown in Fig. 1 in which each photosurface of the 3D camera is shuttered by its own shutter.

Combination unit 222 preferably comprises an adjustable neutral density filter 240 located between taking lens 35 and four-way prism 236. Neutral density filter 240 is chosen so that it does not substantially attenuate IR light. Neutral density filter 240 is used to control the amount of visible light 48 collected by taking lens 35 that reaches color cameras 230, 232 and 234. The amount of IR light 60 reaching 3D camera 226 is controlled by iris 67 comprised in taking lens 35.

In the description and claims of the present application, each of the verbs, "comprise" "include" and "have", and conjugates thereof, are used to indicate that the object or objects of

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the verb are not necessarily a complete listing of components, elements or parts of the subject or subjects of the verb.

5 The present invention has been described using detailed descriptions of preferred embodiments thereof that are provided by way of example and are not intended to limit the scope of the invention. The described preferred embodiments comprise different features, not all of which are required in all embodiments of the invention. Some embodiments of the present invention utilize only some of the features or possible combinations of the features. Variations of embodiments of the present invention that are described and embodiments of the present invention comprising different combinations of features noted in the described
10 embodiments will occur to persons of the art. The scope of the invention is limited only by the following claims.

ART 34 AMDT

CLAIMS

1. An optical imaging system comprising:
 - a taking lens system that collects light from a scene being imaged with the optical
 - 5 imaging system;
 - a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and
 - an imaging camera comprising at least one photosurface that receives light from the
 - 10 taking lens system and provides a picture of the scene responsive to the light; and
 - a light control system that controls an amount of light from the taking lens that reaches at least one of the 3D camera and the imaging camera without affecting an amount of light that reaches the other of the 3D camera and the imaging camera.
- 15 2. An optical imaging system according to claim 1 wherein the 3D camera and the imaging camera are boresighted with the taking lens system.
3. An optical imaging system according to claim 1 or claim 2 wherein the at least one photosurface of the 3D camera and the at least one photosurface of the imaging camera are
- 20 homologous.
4. An optical imaging system according to any of the preceding claims wherein the light control system comprises a light controller adjustable to control the amount of light from the taking lens system that reaches the imaging camera without affecting the amount of light from
- 25 the taking lens system that reaches the 3D camera.
5. An optical imaging system according to claim 4 wherein the light controller comprises an iris.
- 30 6. An optical imaging system according to claim 4 wherein the light controller comprises a neutral density filter.

ART 34 AMD

7. An optical imaging system according to any of the preceding claims wherein the light control system comprises a light controller adjustable to control the amount of light collected by the taking lens system that enters the imaging system.

5 8. An optical imaging system according to claim 7 wherein the light controller that controls the amount of light collected by the taking lens system that enters the imaging system comprises an iris.

9. An optical imaging system according to any of the preceding claims and comprising a
10 light controller adjustable to control the amount of light from the taking lens system that reaches the 3D camera without affecting the amount of light from the taking lens that reaches the imaging camera.

10. An optical imaging system according to claim 9 wherein the light controller that
15 controls the amount of light from the taking lens system that reaches the 3D camera comprises an iris.

11. An optical imaging system according to any of the preceding claims wherein the 3D camera is a gated 3D camera.

20

12. An optical imaging system according to claim 11 and comprising a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the optical imaging system.

25 13. An optical imaging system according to claim 12 wherein the pulsed light source radiates IR light.

14. An optical imaging system according to any of claims 11 - 13 wherein the 3D camera comprises at least 2 photosurfaces.

30

15. An optical imaging system according to claim 14 wherein the 3D camera comprises a light guide that receives light from the taking lens system and directs portions of the light that it receives to each of the at least two photosurfaces.

ART 34 AMENDED

16. An optical imaging system according to claim 15 and comprising a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

5 17. An optical imaging system according to claim 16 and comprising a controller that gates the single shutter open and closed.

18. An optical imaging system according to claim 17 wherein the controller controls each of the photosurfaces to be activated and deactivated and wherein when a photosurface is
10 activated, it is sensitive to light incident thereon.

19. An optical imaging system according to claim 18 wherein each time that the controller gates on the single shutter it activates one and only one of the at least two photosurfaces.

15 20. An optical imaging system according to claim 19 wherein the at least two photosurfaces comprises three photosurfaces.

21. An optical imaging system according to claim 20 wherein following a time that at least one light pulse is radiated, the controller gates on the single shutter for a first gate and turns on
20 a first photosurface and wherein the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

22. An optical imaging system according to claim 21 wherein following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter
25 for a second gate and activates a second one of the photosurfaces and wherein the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

23. An optical imaging system according to claim 22 wherein following a time that at least
30 one light pulse in the train of light pulses is radiated the controller gates on the single shutter for a third gate and activates a third one of the photosurfaces and wherein the controller controls the gate width and timing of the third gate so that during the third gate substantially all

light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

24. An optical imaging system according to any of claims 15-23 wherein the light guide is a three-way prism.

25. An optical imaging system according to any of claims 1 - 24 and comprising a beam splitter that receives light from the taking lens system and directs a portion of the received light towards the 3D camera and a portion of the received light to the imaging camera.

26. An optical imaging system according to any of claims 7 - 23 wherein the light guide is a four-way prism that receives light from the taking lens system and directs a portion of the received light to the imaging camera.

27. An optical imaging system according to any of the preceding claims wherein the imaging camera comprises a color camera.

28. An optical imaging system according to any of claims 1 - 24 wherein the imaging camera is a color camera comprising separate R, G and B photosurfaces and comprising a four way prism that receives light from the taking lens system and directs a portion of the received light to each of the R, G and B photosurfaces and to the single shutter of the 3D camera.

29. A gated 3D camera comprising:
a taking lens system that collects light from a scene imaged with the 3D camera;
at least 2 photosurfaces;
a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces;
a single shutter, which when gated open enables light from the taking lens system to reach the light guide; and
a controller that controls the shutter and the photosurfaces and gates on a photosurface of the at least two photosurfaces by activating the photosurface and subsequently gating the single shutter open and gates off the photosurface by gating the single shutter closed and

subsequently deactivating the photosurface and wherein the controller gates on only one photosurface at a time.

30. A 3D camera according to claim 29 wherein the at least two photosurfaces comprises
5 three photosurfaces.

31. A 3D camera according to claim 30 and comprising a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the 3D camera.

10 32. A 3D camera according to claim 31 wherein following at least one time at which a light pulse in the train of light pulses is radiated, the controller gates on a first photosurface of the three photosurfaces for a first gate period which is timed so that light reflected from the light pulse by a region in the scene is registered by the first photosurface.

15 33. A 3D camera according to claim 32 wherein following at least one time at which a light pulse in the train of light pulses is radiated, the controller gates on a second one of the three photosurfaces for a second gate period which is timed so that during the second gate no light from the light pulse reflected by the region is registered by the second photosurface.

20 34. A 3D camera according to claim 33 wherein following at least one time at which a light pulse in the train of light pulses is radiated, the controller gates on a third one of the photosurfaces for a third gate period and which is timed and has a gate width so that during the third gate substantially all light from the light pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

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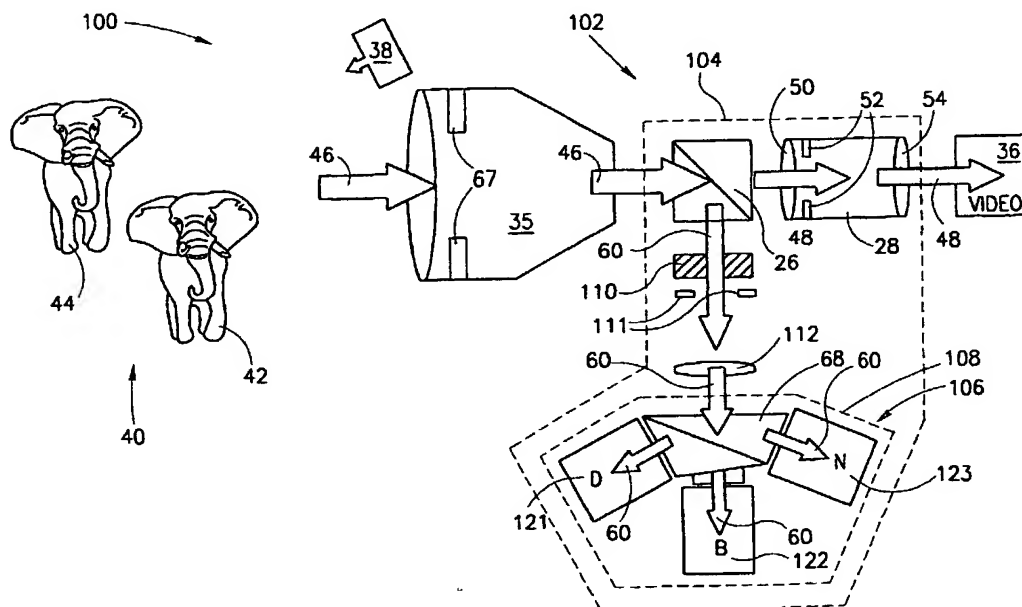
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(54) Title: 3D IMAGING SYSTEM



(57) Abstract: An optical imaging system comprising: a taking lens system that collects light from a scene being imaged with the optical imaging system; a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light.

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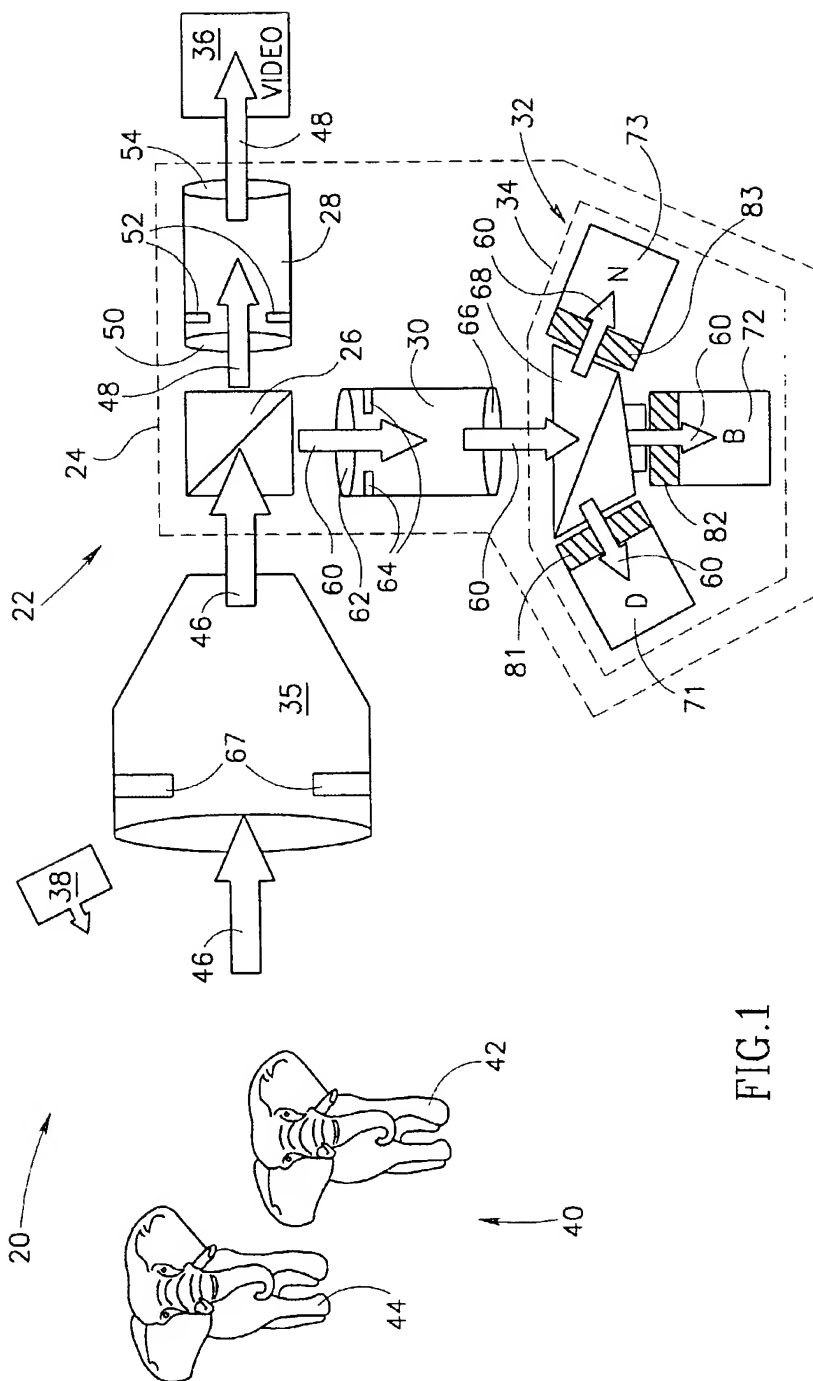
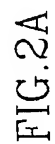


FIG.1



ART 34 AMDT

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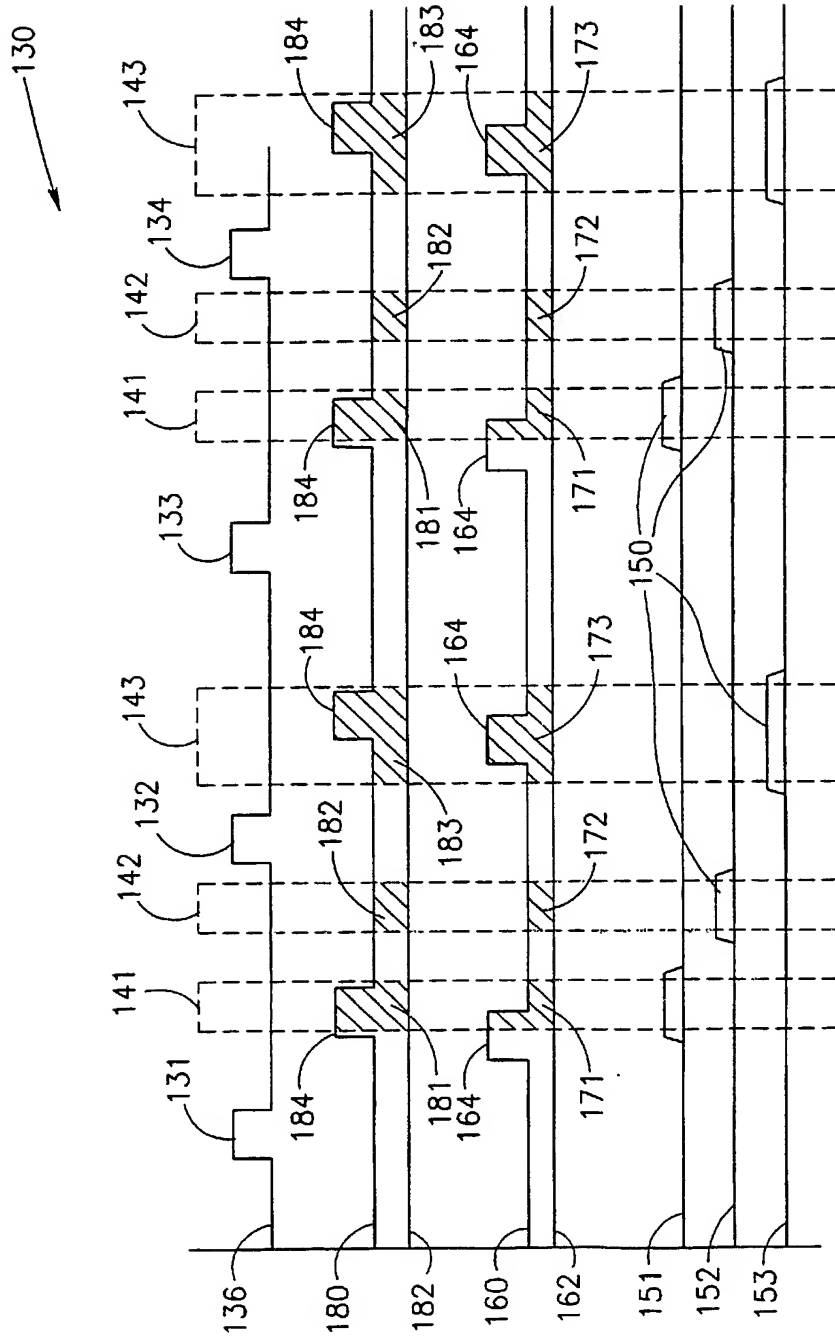


FIG. 2B



FIG. 4

Docket No.
001/02614

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

3D IMAGING SYSTEM

the specification of which

(check one)

☐ Is attached hereto.

☒ was filed on September 8, 1999 as United States Application No. or PCT International Application Number PCT/IL99/00490 now USSN 10/070,774 and was amended ~~on~~ as in the annexes to the IPER and on March 6, 2002 (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

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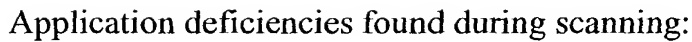
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